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T. S. Lebedev, V. I. Shapoval, V. T. Lakhtanov, and V. A. Korchin

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MEASUREMENT OF THE TIME FOR PASSAGE OF AN ELASTIC IMPULSE THROUGH A ROCK SPECIMEN UNDER HIGH PRESSURE AND TEMPERATURE EXPERIMENTAL CONDITIONS

T. S. Lebedev, V. I. Shapoval,
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ABSTRACT. The improved laboratory installation is described for measuring time of elastic pulses transmission through the rock samples under experimental conditions of high pressures and temperatures. The extremal amplifier of pulses of starting the piezoradiators with the amplitude up to 2000 V with the pulse minimum duration about 0.1 μ sec. This permitted the piezoceramic and quartz transmitters to be applied with the greatest advantages within a wide frequency range (up to 3-4 MHz). To intensify the signals of the piezoreceiver the wide band amplifier is used with a low level of its own noises and interferences. The accuracy of determinations of time for elastic pulse transmission through the sample is ± 0.05 μ sec.

In the Division of Physical Properties of Matter of the Earth, Institute of Geophysics of the Academy of Science Ukrainian SSR, experimental studies have been made of the velocity change of longitudinal elastic waves in rock /59* specimens under quasi-isotropic pressures up to 5,000 kg/cm^2 and temperatures which reached 650° C. In these studies piezo-transducers were used in a wide range of inherent frequencies up to 3-4 Mhz. With the objective of increasing the reliability and raising the accuracy of performing these experiments, we improved the previously described [6] assembly for measuring the time of passage of an elastic impulse through a specimen.

The general block-diagram form of our set-up is given in Figure 1. From the channel output of generator I (G5-4B) into final amplifier III pass trigger impulses whose repetition frequency is of the order of 1 kHz. The amplified trigger impulses exite piezo-emitter IV, which transmits the elastic oscillations

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*Numbers in the margin indicate pagination in the foreign text.

to the sample under investigation V. The signal, received by piezo-receiver VI, is amplified by broad-band pre-amplifier VII and registered on oscillograph VIII (IO-4). The rate of passage of the acoustic impulse through the specimen is determined by the rate of transmission of the trigger impulse into the piezo-emitter and by the time for the first entry of the wave pattern on the screen of the electron-beam tube. The time interval between the trigger impulse and the first entry is recorded by the delayed reference impulse from channel 2 of generator I, which is blended with the piezo-receiver signal in the block of preamplifier VII.

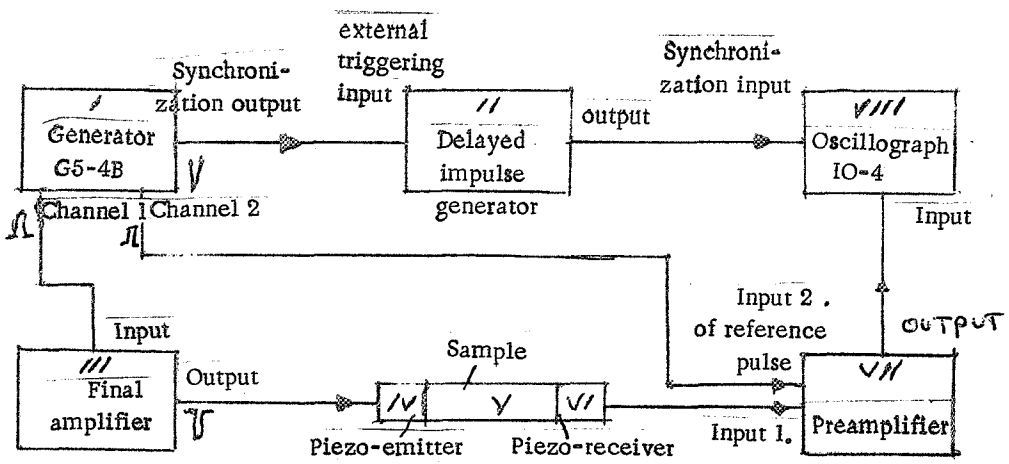


Figure 1. Block Diagram of Assembly for Measuring Time of Passage of Elastic Impulses Through Rock Samples (Institute of Geophysics, Academy of Sciences of the Ukrainian SSR, 1969).

The reading for the propagation time of elastic waves is taken from the delay dial of the G5-4B generator with an accuracy of ± 0.05 microsecond. /60 Synchronization of oscillograph VIII (IO-4) is achieved using delayed impulse generator II, which gives out delayed impulse relative to the trigger impulse of the piezo-emitter from channel 1 of generator I. The trigger impulse of generator II is taken from the synchronization output of the impulses from the G5-4B generator. A G5-15 instrument can be used as the delayed impulse generator II; it has an impulse delay in the range from 0 to 10^3 microseconds.

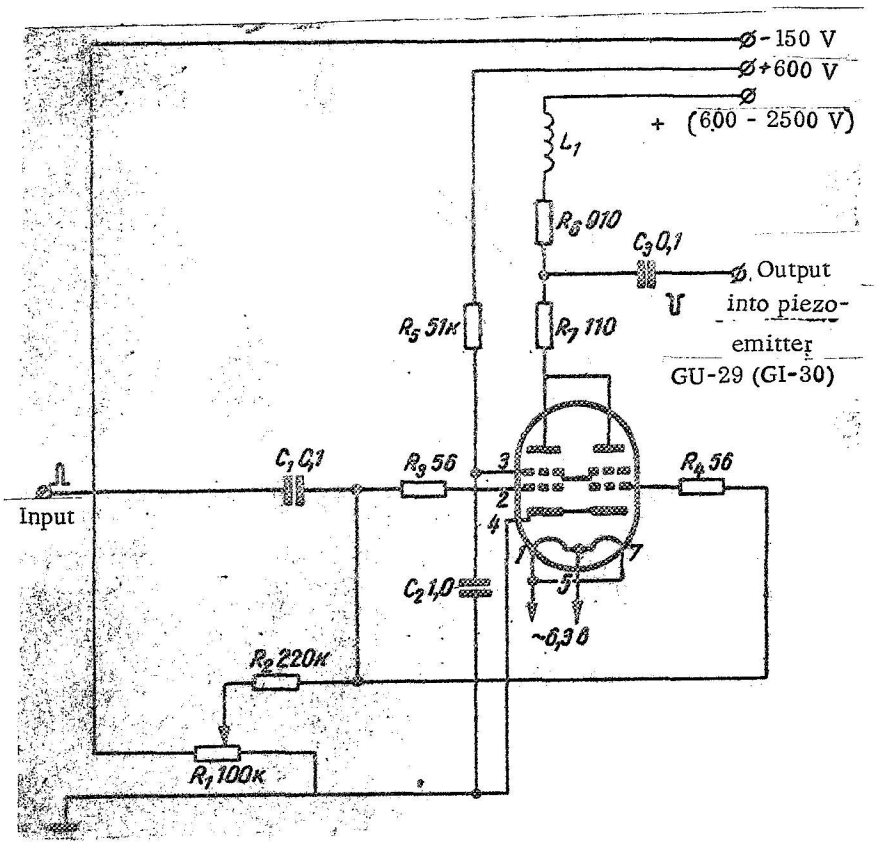
Let us consider the improvements which we have introduced into the scheme of the set-up of [6]. The high-power electrical impulse generator previously developed on the basis of an IPA instrument [4] gave out impulses of 3 to 10 microseconds duration, with an amplitude of the order of 800--1000 V. However, when piezo-transducers with inherent frequencies of more than 1 MHz are used, the required duration of the trigger impulses should be no more than 0.5 microsecond. This is needed to match the generator output with the piezo-emitter and to obtain a sharp first entry of the signal wave pattern assumed by the piezo-receiver VI. Therefore, a final amplifier block for the trigger impulses of the piezo-emitter was developed with parameters which corresponded to the requirements of the experiment (Figure 2). Into the input of the amplifier are fed additional impulses of an amplitude of the order of 100 V, from channel 1 of generator I (G5-4B). The duration of the trigger impulses is regulated from 0.1 to 10 microseconds. From the anode of the GU-29 (GI-30) lamp is taken a negative square impulse, which triggers the piezo-emitter. The impulse amplitude is regulated by changing the feed voltage. A negative bias on the controlling grid of the GU-29 (GI-30) lamp is established by potentiometer R_1. The resistance of resistor R_6 is chosen small to obtain a sharp output impulse front. /61 The inductance L_1 is a high-frequency correction element. Resistor R_3, R_4, and R_7 are anti-stray resistors. The final amplifier made up according to this scheme gives out output impulses with an amplitude from 400 to 2000 V and a duration of 0.1 to 10 microseconds. The duration of the leading front of the impulses is no more than 0.03 microsecond. This makes it possible to use the piezo-emitters over a wide frequency range at a large output mechanical vibration power.

A considerable damping of elastic vibrations takes place in rocks at high pressures and temperatures. This causes a decrease in the level of the effective electrical signal which is directed into the piezo-receiver. Moreover, the piezo-efficiency of the transducers is reduced because of a certain amount of warming. The factors considered require the use of a preamplifier for the piezo-receiver signals which has a low level of inherent interference and noise. Therefore, a low-noise wide-band preamplifier for the piezo-receiver signals was developed (Figure 3). To lower its sensitivity threshold and obtain a

high-ohm input, the first stage was made by a cascade scheme with a free (floating) grid [1,2,3]; the others, (tubes L_1, L_2) by the usual scheme (a rheostat amplifier with high-frequency and low-frequency correction). L_1, L_2, L_3, and L_4 are elements of the high-frequency correction. R_6, C_2, R_{11}, C_4, R_{12}, C_6, R_{19}, C_7, R_{21}, and C_{10} are elements of the low-frequency correction. Resistors R_7, R_{14}, R_{16}, R_{24}, and R_{27} are suppressor-type. Amplification control is achieved with potentiometer R_{13}, which is included in the cathode circuit of the right half of tube L_2. To match the preamplifier output with the low-ohm cable which transmits the signal to the oscillograph, its final stage (the left half of tube L_4) is made by a cathode follower scheme. On the grid of the right half of tube L_4, through differentiating circuit C_{13}, R_{31} is fed a delayed /62 reference impulse from channel 2 of the G5-4B generator, using the given preamplifier according to the block diagram (see Figure 1). The cathode of the right half of tube L_4 is connected to resistor R_{29}, therefore the reference signal is blended with the piezo-receiver signal. The preamplifier has small dimensions and can be placed in direct proximity to the piezo-receiver, which improves the signal/noise ratio. Its properties are as follows: amplification-coefficient, of the order of 6×10^3; frequency band transmitted, 100 Hz--3 MHz; noise level brought to input, of the order of a few microvolts. The use of this preamplifier makes it possible to obtain a sharp first entry of the wave pattern on the screen of the electron-beam tube of the oscillograph.

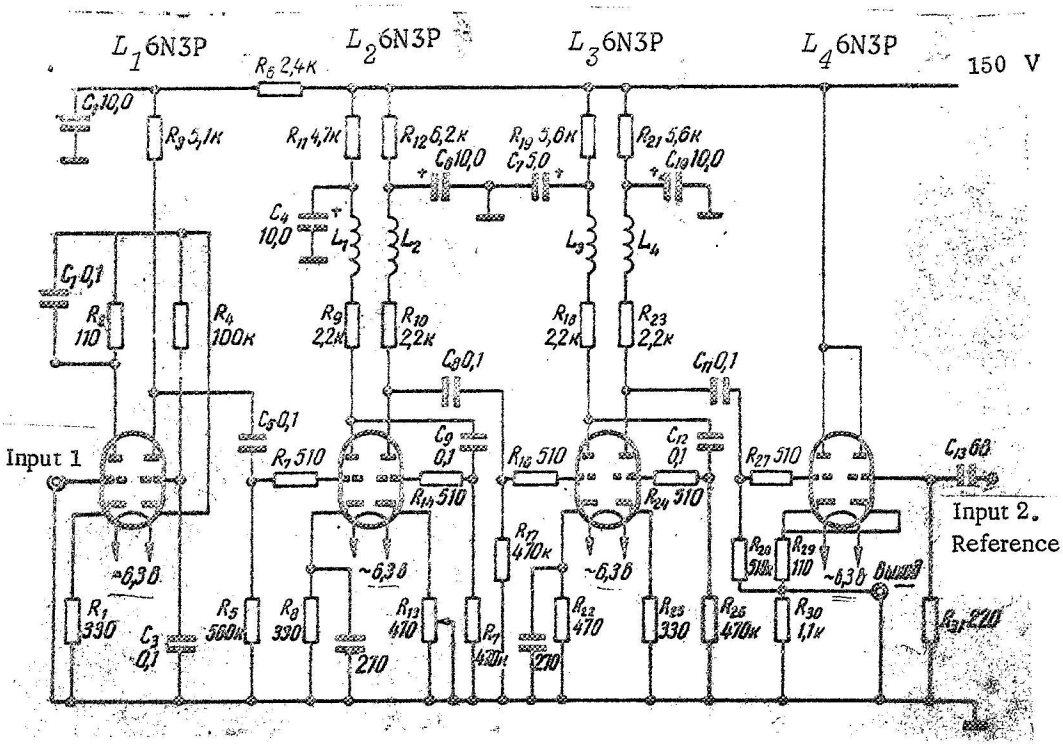
To improve the parameters of the measuring circuit of the set-up, we also developed a second preamplifier variant using super-miniaturized metal-ceramic tubes, which have better service characteristics than ordinary tubes [5]. The metal-ceramic tubes (nuvistors) are characterized by a low noise level, an insignificant microphonic effect, high cathode stability, and great reproducibility of parameters from tube to tube; they are quite economical, and they have small dimensions and weight. The diagram of a wide-band preamplifier using metal-ceramic tubes is given in Figure 4. It is basically analogous to the preceding scheme (see Figure 3). The parameters of the nuvistor preamplifier are as follows: frequency band transmitted, 1 kHz--4MHz; amplification efficient--10^4; noise level brought to input, 3 to 4 microvolts.

The assembly described is used in studying the velocity change of longitudinal elastic waves in rock samples at pressure up to 5,000 kg/cm^2 and temperatures which do not exceed 650° C. The accuracy of the velocity measurement is 1--1.5%.



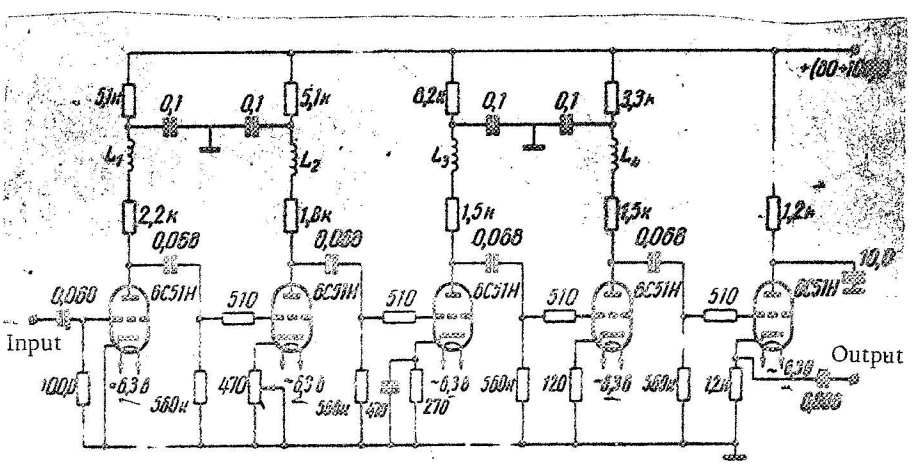
Translator's Note: Commas indicate decimal points.

Figure 2. Final Impulse Amplifier for Excitation of Piezo-Emitter.



Translator's Note: Commas indicate decimal points.

Figure 3. Wide-Band Piezo-Receiver Signal Preamplifier.



Translator's Note: Commas indicate decimal points.

Figure 4. Wide-Band Preamplifier Based on Metal-Ceramic Tubes.

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